Unidad de Políticas Comparadas (CSIC)
Working Paper 04-15

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December 2004

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***Abstract***

Research quality is the cornerstone of modern science, it aids in the understanding of reputational differences among scientific and academic institutions. Traditionally, scientific activity is measured by a set of indicators and well-established bibliometric techniques based on the number of academic papers published in top-ranked journals or on the number of citations of these papers. These indicators are usually critical in measuring differences in research performance, both at individual and at scientific institutional levels. In this paper, we introduce an alternative and complementary set of indicators based on the results of competition for research funding, that aim to enlarge the framework in which research performance has traditionally been measured. Theoretical support for this paper is found in the role that the search for funding plays in the researchers' credibility cycle as well as in peer review, the basic instrument for the allocation of public R&D funds. Our method analyses the outcomes of the researchers' struggle for funding, using data from research proposal applications and awards, as the unit of observation, and aggregating them by research institutions to rank them in relative scales of research competitiveness.

***Key words**: Science policy, Government research project funding, Third party R&D funding, Research indicators, Research competitiveness, Peer review.*

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Sociologists of science [Merton (1957), Zuckerman (1965) or Cole and Cole (1967)] noted that individual reputation and credit within the scientific community have been critical in knowledge diffusion and the emergence of the social structure of science. The diffusion of scientific ideas subject to control mechanisms—peer review—and the competition in research introduce differentiation among scholars and research outcomes. The leading scientists in any discipline are the ones who earn their colleagues' recognition. Institutions also gain legitimacy and the reputation as high-quality research centres, based on their researchers' recognition.

* The authors are grateful for the funding from the Directorate-General for Research of the Ministry of Education and Science (SEC-2001-2411-C02-01; SEJ-2004-08052-C02-01/SOCI), the participation in the EU Network of Excellence PRIME (CIT1-CT-2003-506596) and P. Barrios and R. Meza's work on the preparation of the databases. Suggestions from two anonymous reviewers are also acknowledge.

In this context, major efforts were devoted to measuring scientific production [De Solla Price (1963)], basically focusing on the volume and quality of scientific publications [Garfield (1972)]. Despite controversies and researchers' claims about the meaning of quality based on bibliometric indicators and methodological concerns [Van Raan (1988), Moed (2002)], there is general agreement that the metrics of scientific excellence cannot be disentangled from peer review.

Peer review has been the basic quality control mechanism [Zuckerman and Merton (1971)] shaping the evolution of science since knowledge diffusion in printed form became dominant; it makes research outputs authoritative, and legitimates both authors and journals, even though it has itself been questioned [Campanario (1998), Cole (1998)]. However, peer review is also critical in monitoring and assessing the efficiency and legitimacy of R&D investments made by governments [Spence (1998)]. In this context, peer review acts as an effective mechanism in at least two ways. First, it provides legitimacy to public bodies [Rip (1994)]; and, second, the results of peer review contribute to scientific reputation [Latour and Woolgar (1989)].

Modern science policies are preferably developed through competitive research funding, in the context of peer review processes; different forms of peer review thus play an essential role in allocating resources for research. However, the analysis of the outcomes of the distribution of competitive R&D grants has not attracted a lot of attention in empirical studies[1]. Some cases exist, such as the DFG (German Research Council) [DFG (2004)], that publish rankings of funding, in addition to third-party funding that has been used as an indicator [Hornbostel (2001) for German universities] and associated with the traditional bibliometric indicators [Moed *et al* (1998) for Flemish universities].

The results of the competition for funding represent another differentiation variable among research institutions with regard to their research capabilities and effort and their competitiveness. Public R&D funding under competitive rules is not exclusively a policy issue related to the efficient allocation of public resources, but also a critical mechanism embedded in the mode of operation of research activities. From this standpoint the use of indicators resulting from competition for funds may contribute to consolidating the use of multiple and complex indicators for measuring research activities [Martín (1996), Laredo and Mustar (2000)].

[1] But the use of applications or the projects granted for measuring prestige, recognition or research performance is not a new idea, for instance: Hagstrom (1971), Jauch and Glück (1975); Harter and Hooten (1992), etc.

The aim of this work is to make up for this deficiency and construct indicators, through the use of data of competitive funding of research projects of the Spanish government. This paper is devoted to measuring the research competitiveness[2] of Spanish public research centres and universities, and the institutional reputation-building based on the competition for national government R&D funds subject to peer review[3]. The method used analyses the results of the competitions held among researchers for public R&D funding, using research project applications and awards as the unit of observation and aggregating them by research institutions.

First, we analyse the theoretical robustness of the procedure, which is based on the role that the search for funding plays in the researchers' credibility cycle and in the award of public research grants through procedures based on the peer review system. Next, the science policy context in Spain is reviewed, and competitive research-funding procedures are analysed to provide a frame for understanding. After that, the data and indicators built are described. Finally, aggregate results are presented on competitiveness of Spanish research institutions in all fields of research, and more detail is given in particular for social and economic sciences.

## The results of the competition for research funding as an indicator

In this section, we will try to provide an answer on whether it is legitimate, from a theoretical standpoint, to represent certain aspects of research activity based on the results of the competition for government funding, when the peer review system is used. As arguments to support the proposed construction of indicators, we will see the relationships between science and government through funding and the role played by recognition and reputation of researchers in the way science operates.

The relationships between governments and science, under the sponsorship model, go far back; initially, governments supported research through the creation of governmental R&D centres in specific areas, such as geology, agriculture or defence. Later, fundamental

[2] A new concern has recently emerged about the identification of "centres of excellence" based on quantitative methods, with steps in this direction having been taken using bibliometric techniques [for instance, Tijssen (2003) or Van Leeuwen *et al* (2003)]. The analytic importance of identifying centres of excellence is the result of new research policy demands; in addition, the implications of bibliometric studies in research policy are increasingly being analysed [Luwel, Noyons and Moed (1999) or Rinia (2000)], their use in the context of peer review processes is being developed [Van Raan (1996)] or bibliometric tools are being constructed for decision-making in R&D funding policies [Debackere and Glanzel (2004)]. However the focus of this paper is not scientific excellence but research competitiveness, no matter that both are related.

[3] Our analysis is restricted to the distribution of research funding made by the central government to control the effects of regionally-funded monopolies that have emerged from the proliferation of public R&D programmes supported by regional governments.

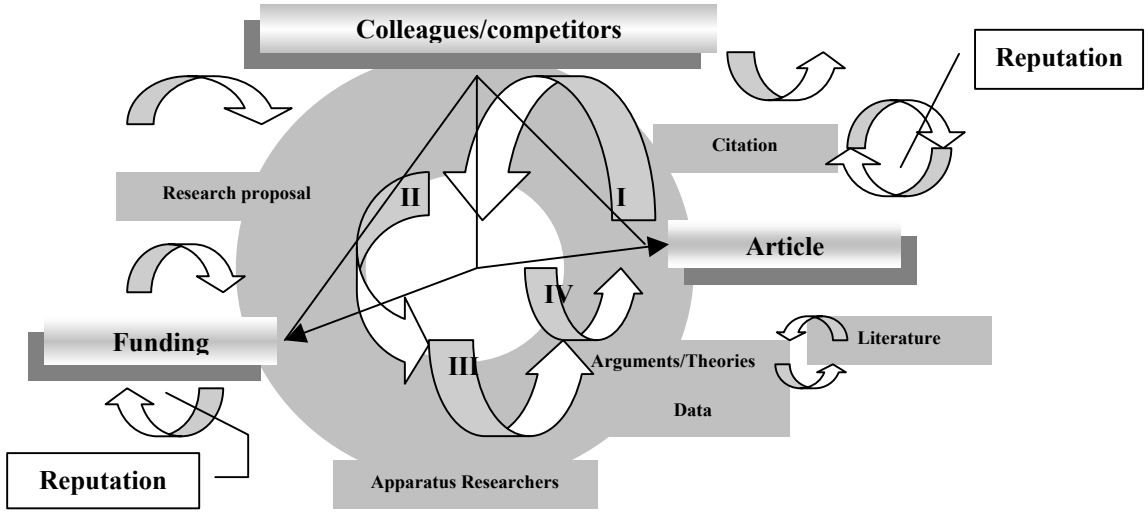
research funding by governments was assumed as an obligation [Bush (1945)], not only because it provided a "social contract" with the researchers [Price (1965)], but also because it was justified by economic theory [Arrow (1962), Nelson (1959)]. Thus, public funding became a conditional factor that made research possible in the public sector and at universities, and at the same time, it guaranteed the independence of researchers as opposed to corporate pressure in the appropriation of research outcome.

Nowadays, research policies are associated with competition for funding. A group of specific intermediary institutions (research councils or funding agencies like NSF or NIH) arose to administer resources, but at times, as in the case of Spain, the steering and funding of research is administered within ministerial structures but in conditions and functioning procedures that somewhat resemble those of Research Councils, thus we have labelled the Spanish situation as "quasi Research Council". In these cases, the allocation of resources bases its legitimacy on the involvement of scientists themselves in the evaluation processes, who, at the same time, facilitate the definition of public priorities in research matters [Braun, (1993), Guston (2000)]. Therefore, research councils or the administrative mechanisms that take their place are vehicles for exchanging resources for legitimacy [Rip (1994)].

Receiving recognition and credit for contributions form part of the mechanisms of competing and struggling for the feasibility of theories; reputation and credit are achieved through the diffusion of discoveries. Competition is an essential part of research activities [Hagstrom (1974)] and being the first to make a discovery and achieving peer recognition are key aspects in research careers [Dasgupta and David (1994)]. The traditional "*credibility*" cycle that is established by means of a cognitive connection between production, communication and collective evaluation of the results is expanded through the addition of the processes of competing for public funds needed to carry out research[4]. Latour and Woolgar (1979) introduced research funding as part of the cycle of scientists' reputation and credibility (figure 1).

[4] Funds are money. Awarded funds are reputation, either. Therefore, researchers are competing for funds. But competition for funds by the researchers is from its very essence not the same as their competition for scientific results.

**Figure 1. The credibility cycle for a scientist**




Source: García and Sanz Menéndez (2004) adapted from Rip (1994) and Latour and Woolgar (1979)

Under regular conditions, the process of allocating financial resources for research is mediated by peer review, the main quality control mechanism in science[5]. In the peer review of research projects applying for funding, it is well known that, in addition to the content of the project, peers normally take key aspects of the applicants' reputation or credibility into consideration, based on their past performance or on their institutional affiliation. Moreover, if there is uncertainty or a lack of information, peers tend to use indirect elements for their judgment, such as the journals in which the applicant has published, or the institution or department with which he/she is associated, which become cognitive devices in making the decision about whether the research project should be funded or not. There is a connection between peer review and the publication results; for this reason, there is an increased interest in determining the relationship between peer review judgments and the bibliometric analysis, for instance Rinia *et al* (1998) or Aksnes and Taxt (2004).

Thus, competition for funds is an essential mechanism in the cognitive functioning of research, articulated in the credibility cycle, and a vehicle for relationships between science and government. This paper focuses on the left side of the credibility cycle (figure 1), and should be complemented with the right side, or more conventional bibliometric analysis[6]. Our basic assumption is that, whenever competition and reputational issues are at stake, observed differences may be explained by peers' perception of "quality". While in making this assumption we are also aware that "research quality" thru competitive funding is mainly local –i.e. country level- and shaped by the level of funding and policy targets. Therefore, in

[5] It is also known that peer review also has serious drawbacks [Cole, Rubin and Cole (1978), Chubin and Hackett (1991)].
[6] In a further extension of this paper we will test the relationships between both research funding and realized research publications.

specific context, the use of the results in the struggle for funding, has sufficient theoretical justification as an indicator of research competitiveness.

## Contextualising research funding indicators in S&T policy

In this section, we will present some elements of the Spanish S&T policy, necessary to assess the feasibility of using research funding data as an indicator of research competitiveness.

Until the early Eighties, the Spanish research system was underdeveloped. The level of R&D investment was marginal; in 1981, it was 0.43% of the GDP, less than 20% of the OECD average. Most research in the public sector took place in Government Research Centres, mainly the CSIC. Spanish universities were teaching universities. Major reforms were implemented by the socialist government in the early eighties (Sanz-Menéndez, Muñoz and García, 1993; Sanz Menéndez, 1997). First, there were changes in the university structures, prompted by the *University Reform Act* of 1983, which allowed them to adopt the *"Humboldt"* model and create University departments as the basic units of activity, and also changes that occurred in public research centres (Sanz-Menéndez and Cruz, 2003). Second, new incentives were provided for professors and researchers to become involved in research (Jiménez-Contreras *et al*., 2003), technology transfer[7] and service to society (García and Sanz-Menéndez, 2003). And third, new forms of policy intervention were implemented, from direct funding of R&D activities dominant until the end of the 1970s to indirect funding mechanisms, based on competition through peer review selection guaranteed by the state (Sanz-Menéndez, 1995).

However, it was not until the mid-1980s when the dramatic growth in the budget earmarked for competitive R&D and the central role of peer review in allocating funding were witnessed. The new arrangements were institutionalised in 1986 by means of the Act for the Promotion and General Coordination of Scientific and Technical Research (Science Act). Under the new Science Act, the funding of research activities was organised around a National R&D Plan including: (1) targeted research, articulated around priority programmes, and basic research articulated by the programme for the General Promotion of Knowledge

[7] Moreover, the University Reform Act (1983) also allowed Universities to enter into research contracts with third parties, mainly firms and other organisations, and provided individual incentives to increase the level of scientific activity, though the outcomes and quality of such activities are hard to capture through conventional scientometric measures.

(PGC)[8]; and (2) peer review as the legitimate selection mechanism prompted by the creation of the National Agency for Evaluation and Assessment (ANEP).

In Spain, the evolution of the university and of R&D centres was not independent of the efforts made by the government, as government authorities wanted the growth of R&D funds to be centralised, ensuring competition for funds and targeting research towards national priorities, always with decisions made using peer review-based procedures. In a few years, the change had been made from direct to indirect execution of research, with the creation of competitive funds for research awarded through peer review-based mechanisms.

Government funding by the national government for R&D in the public sector is highly concentrated. Nearly all of the central government's competitive funds earmarked for funding the public research sector have traditionally been under the Ministry of Education and Science, in the State Secretariat for Universities and Research[9], although there were another two separate sectoral funds for biomedical research and agricultural research[10] which however never even reached 10% of the central government's total competitive funds for the public research sector.

The primary mechanism of action of Spanish R&D policy has been the funding of research projects, and this has accounted for most of the non-specific objective funds, discretionary or programmable expenditures, earmarked for the public research sector. In 2001, research projects amounting to nearly 190 million euro were approved, with the peculiarity that these projects did not include the labour cost of permanent researchers or research equipment, which was funded through other specific calls for proposals; it was limited to only small equipment and temporary contracts. In addition, the rules of the calls for proposals stated that researchers could only be active in a maximum of one full-time or two part-time R&D projects, so the diverse individual tendencies of researchers to present proposals are controlled.

[8] The structure of the National R&D Plan in targeted and non-targeted programmes was actually rhetorical, as it did not have—ex ante—any resources assigned by areas, but waited for the demand received for funding and the quality of the proposals. Thus, the funds that were granted were doubly competitive, as some scientific areas competed with others in the allocation of funds for projects, and because some proposals competed with others in the same areas in terms of quality and priority for funding.

[9] The funds were first administered from the Secretariat-General of the National R&D Plan and the State Secretariat for Universities and Research of the Ministry of Education and Science (MEC), and later, between 2000 and 2004, from the Directorate-General for Research (DGI) of the Ministry of Science and Technology. The programmes included in the analysis were all National R&D Programmes, as well as the General Promotion of Knowledge (PGC) programme, both part of the National R&D Plan.

[10] The Health Research Fund (FIS) has funded biomedical research in the national health system [Clavería et al (2000)], and the sectoral agricultural research programme was managed from the INIA (National Institute of Agro-Food Research and Technology).

These budget funds were awarded through an annual public call for proposals. The peer review system implemented is a two-stage process in which two or three individual peers, using a mail procedure, first assess the submissions, and then a panel of experts makes the final funding decisions. The Spanish peer review model has been built upon two critical figures, usually both academics in part time jobs: (1) the coordinator of each scientific area, appointed by the National Agency for Evaluation and Assessment (ANEP); and (2) the manager of each scientific programme. Coordinators select the peers from a pool of academics, based on a mix of criteria such as scientific specialisation, research expertise, etc. Programme managers are responsible for appointing the panel of experts (between 8 and 20) that will complement the assessment of each project. The new scores, together with the scores from ANEP, contribute to the final decision on whether or not the proposal is funded. The evaluation criteria were the usual ones: contribution of the proposal, research design, methodology and past performance of the principal researcher and research team. In any case, what is relevant for the validity of the indicators that we will define below in the context of Spanish science policy is the fact that a competitive research funding system exists.

As opposed to the traditional models for tracking R&D activity, R&D expenditure and human resources indicators, or the recent explosion of bibliometric publications in Spain (for instance, Gómez-Caridad *et al* (2004), de Moya *et al.* (2004), de Moya and Solis (2003), etc.), here we propose to use the data from funding obtained through competition among researchers, from a single funding source –the national government- as a first step in analysing the research competitiveness of the public actors as a whole in the Spanish R&D system[11]. It is a question of comparatively measuring, on a national scale, the activities and relative rank of the actors in research. The comparative position of the groups, of the departments, and above all, of the universities and R&D centres can be analysed through the results of the competition among researchers for public funding, using different levels of aggregation.

How can the results of these calls for research proposals decided by the peer review procedure become comparative indicators of research activities? The two basic structural conditions are present: For the researchers, it was prestigious, and also, because of the lack of their own funds, having them compete for resources was necessary for the institutions. On one hand, the paucity of budgets that Spanish universities and R&D centres can earmark for

[11] The validity of the construction of the indicators depends on how widespread peer review is in the selection process. In addition, data is available in extensive time series to incorporate the cycles of seeking funding, and calls for proposals include all areas and disciplines, so that the snapshot is consistent with research as a whole. This will let us, on another occasion, compare the results with bibliometric indicators.

funding their own research makes the search for outside funding decisive in carrying out their R&D. The internalisation by academics of the mechanisms of competing for resources that ensure the possibilities of an individual's work gives researchers a strong incentive to fight for funding. On the other hand, having a project funded by the National R&D Plan is an element of prestige in all fields of research in Spain, so the fact that professors tend to be research-oriented with a propensity to compete for national research funds can be assumed. The approval of projects has both reputational value and financial value, making it possible to carry out research that could not be funded by other means.

In short, researchers must communicate research results to achieve legitimacy from their peers, and to obtain results they need funds for which they must compete with other colleagues. If publishing is part of the activities necessary to be a researcher, presenting and getting approval of research projects is too.

## Data, methods and indicators

The data used in this paper comes from the database of the Directorate-General for Research of the Ministry of Education and Science. Data was extracted from research project proposals that Spanish researchers, from all regions and public R&D centres, used to apply for funding between 1996 and 2001 in all scientific areas[12]. The units of observation are the research projects, which all tenured researchers, individually or as a team, can present to compete on equal terms. A set of subprogrammes and actions have been eliminated that were not strictly competitive in nature.

Our basic unit of observation is the research proposal, aggregated at the level of the research organization for comparative purposes. The study of funding obtained by the researchers, and its aggregation by centres, is empirically manageable and also theoretically relevant with regard to the way R&D systems function and, more critically, concerning the differential levels of competitiveness exhibit by the Spanish research institutions.

[12] It has been pointed out that R&D funding based on peer review may be distorted by the social structure of scientific networks within each discipline [Viner, Powell and Green (2004)]. To avoid such potential bias, our analysis refers to aggregate figures from 1996 and 2001. This aggregation lets us control any bias associated with the makeup of the evaluation committees –peers- and contributes to the robustness of our results, since these years correspond to the implementation of two National R&D Plans.

We analyse research competitiveness[13] of Spanish public institutions through three dimensions, and 5 indicators, extracted from the results of the competition for funding. Research competitiveness represents a construct with multiple meanings referring to:

1. ***How much research is a specific organization doing compared to others?*** This question is represented by the share of a single institution compared to the total public research sector in Spain, and it may be described as **research capabilities** and split it into two indexes:

***$RC_1$:*** share of applications [R&D proposals submitted by institution$_i$/∑R&D projects by all competing institutions] , and

***$RC_2$*** referring to the share of awards by institution [R&D awards by institution$_i$/∑R&D awards by all competing institutions].

***$RC_1$*** refers mainly to *potential capabilities* while ***$RC_2$*** represents the *effective capabilities* as recognized by peers. The difference between ***$RC_2$*** and ***$RC_1$*** represents the general competitiveness exhibited by each research organization based on real versus expected returns.

2. ***How well is a specific organization performing as compared to those that are similar in size and nature?*** We could analyses the relative **research effort** in the search for competitive funding in relation to their available human resources. It is the ratio between the share of the total proposals presented, or projects approved, by institution and the share of the total number of researchers that the institution has. There are two alternative indexes:

***$RC_3$*** referring to the applications presented [R&D projects submitted by institution$_i$/Faculty size institution$_i$] and

***$RC_4$*** referring to the number of awards [R&D awards by institution$_i$/Faculty size institution$_i$].

The first may be used as a proxy of the effort that the researchers from each university are doing in the funding race, while the second refers to the impact of recognition through the selection process

3. ***Is a specific research organization doing the best it can regardless of what other competing centres are doing?*** This is measured, for each institution, by the ratio between the number of awards and the total number of R&D projects submitted (***$RC_5$***). The aggregate **success ratio** is a strong measure of the research competitiveness of each institution. Because

[13] Independent variables for the explanation of differential effort and success ratios exhibited by institutions have been gathered from official statistics. Among these independent variables, we include the size of each institution, defined as the number of tenured faculty members in a reference year.

the final outcome (grants) is the result of a double peer review process, the individual rate of success of each institution implies not only the competitiveness of each institution and its researchers in the national funding race but the *"local"* recognition of its research distinctive features and competencies.

All indicators correspond to each university and/or research institution, and they are the compounded effect of all the scientific fields in which they carry on their research activities.

24,144 R&D projects were presented for funding in the six calls for proposals for public government grants between 1996 and 2001. The calls for proposals correspond to two National R&D Plans, which means that it can be assumed that the researchers had the chance to present and/or obtain funds for at least two R&D projects, because these are on average 2.8 years long. Table 1 shows the basic statistics of the number of proposals and awards per institution.

**Table 1. Basic descriptive statistics of Public Research Funds Competition. All research fields. 1996-2001.**

| | Valid N (institutions) | Mean | Confid. -95,000% | Confid. 95,000 | Sum of projects | Minimum No. projects | Maximum No. projects | Variance | Std.Dev. | Standard Error |
|---|---|---|---|---|---|---|---|---|---|---|
| Institutions submitting | 336 | 71.86 | 47.259 | 96.455 | 24,144 | 1 | 2,753 | 52,541.25 | 229.22 | 12.5049 |
| Institutions Awarded | 204 | 64.22 | 38.699 | 89.733 | 13,100 | 1 | 2,037 | 34,165.94 | 184.84 | 12.9414 |

| | Valid N (projects) | Mean (euros) | Confid. -95,000% | Confid. 95,000 | Sum of funding (euros) | Minimum (euros) | Maximum (euros) | Variance | Std.Dev. | Standard Error |
|---|---|---|---|---|---|---|---|---|---|---|
| Total funding (per grant) | 13,100 | 57,713 | 56,457 | 58,969 | 756,038,983.55 | 1,177.98 | 3,207,151 | 5379939249 | 73348.1 | 640.845 |

**Source: Our own work using Directorate-General for Research (MEC) data**

Applications for funding come from all types of non-profit R&D entities and organisations; of these applications, 13,100 projects were funded, which means an average success rate of 54.26% of the total presented[14]. Public research institutions, including public universities, represent 89.3% of total R&D submissions, 92.8% of the final granted R&D projects and 91% of total national public funds delivered, indicating the presence of a strong bias towards public research organizations and the marginal role played by both non-profit organizations, foundations and private universities in the Spanish research arena.

## An aggregated assessment of institutional research competitiveness

In this section, some results of the application of the indicators that were defined earlier are presented to verify their viability. As we have mentioned, the applications and the funding granted for research projects, taken as the result of the competition by researchers for R&D

[14] Considering the success rates that exists in the competition for funds, in Spain, most probably we could say that all good proposals are approved. In fact we will be very hesitant to apply the method for funding programs, such the EU R&D FP, in which the average success ratio is below 20% and result could be somehow random.

funding, provide significant information about the level of research competitiveness of the Spanish public universities and national R&D centres[15].

### Research capabilities of the public research institutions

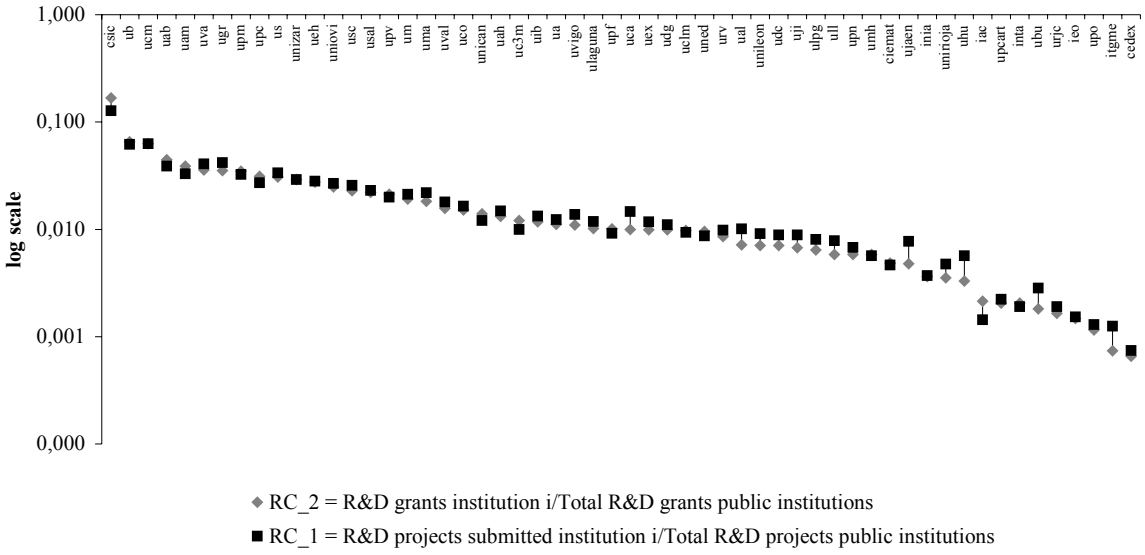
Spanish researchers from 336 different institutions presented applications for funding, but projects were only funded for researchers from 204 institutions. However 56 public research institutions accounted for 89.3% of the total number of R&D projects submitted and 92.8% of the total number of R&D grants. Figure 2 shows the distribution of indicators $RC_1$ and $RC_2$.

Potential research capabilities ($RC_1$) are concentrated in such a way that the top ten public research institutions account for 50% of the total; the concentration is greater in effective research capabilities ($RC_2$) in which those institutions represent 54.7% of the total. Moreover, one individual institution (CSIC) emerge as the dominant actor within the Spanish research system, representing 12.8% of the number of R&D proposals submitted by public research institutions[16] and getting 16.8% of the number of R&D grants funded. Public universities with the highest $RC_2$ figures are: Barcelona –ub- (6.53%), Complutense of Madrid –ucm- (6.29%), Autónoma of Barcelona –uab- (4.46%), Autónoma of Madrid –uam- (3.89%), Valencia –uva- (3.59%) and Granada –ugr- (3.53%).

Now we will observe the difference between the share of R&D grants of each institution ($RC_1$) and the share of R&D proposals submitted ($RC_2$). This is a rough measure of competitiveness but indicates the relative positioning of each research centre. Figure 2 shows that differences are small but four out of the eight National Research Centres, the CSIC and the IAC among them, have captured a share of R&D awards above their share of applications, while only twelve public universities have done better in terms of R&D grants -%- as compare to R&D submissions. The later include the three engineering universities –Cataluña (upc), Madrid (upm) and Valencia (upv)-, Autónoma of Barcelona –uab-, Autónoma of Madrid –uam-, Carlos III of Madrid –uc3m-, Pompeu Fabra –upf-, Cantabria –unican-, UNED, Castilla La Mancha –uclm- and Miguel Hernández –umh-. In the other hand, the institutions with the lower levels of competitiveness measured as the distance between $RC_1$ and $RC_2$ correspond to the following universities: Cádiz –uca-, Málaga –uma-, Jaén –ujaen-, Huelva –uhv-, Burgos –ubu- Vigo –uvigo- and Almeria –ual-.

[15] For those interested in the detailed data of Spanish research actors see Sanz-Menéndez and Barrios (2003); Sanz Menéndez (2005).
[16] Private universities has been removed from this account as they play a minor role.

**Figure 2. Research capability. Spanish public research institutions in the competition for public funding. All research fields. 1996-2001.**

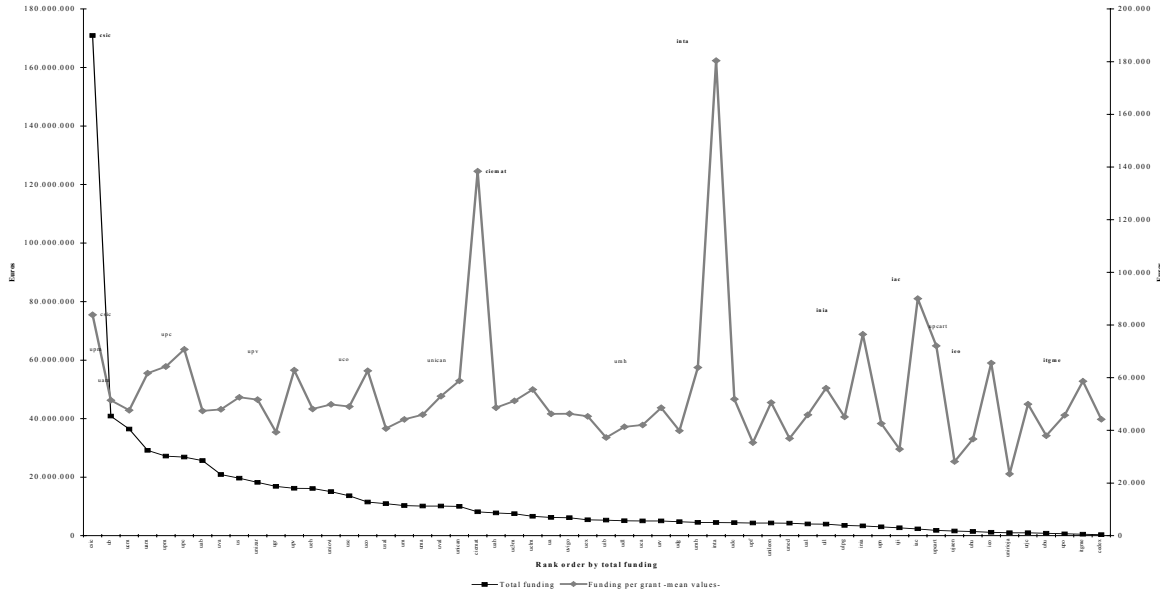



**Source: Our own work using Directorate-General for Research (MEC) data**

To complement this analysis, it should be noticed that the distribution of the amount of funding also shows high levels of concentration. Public research institutions as a whole accounted for somewhat more than 91% of the total budget awarded to fund R&D projects, while CSIC represented around 22.6%. The distribution of R&D funding by institution is highly associated to the total number of R&D awards but the average of funding by grant is an indicator of the scientific field of application, the level of competition as well as the level of competitiveness and recognition of each institution in that area. Figure 3 shows this point as well as the rank distribution for both total R&D funding and R&D funds per award. The results lead to the conclusion that both the National Research Centres and the engineering universities have received during this period the higher levels of funding, because the higher cost of the research activities in which they are specialised.

Last data presented point out that the levels of competitiveness, in terms of research capabilities, exhibited by Spanish public research institutions are shaped by the nature of those institutions, favouring mainly National Research Centres, in which research specialization and funding pressures contributes to its differentiation from public universities.

**Figure 3. R&D funds distribution. Spanish public research institutions in the competition for public funding. All research fields. 1996-2001.**




**Source: Our own work using Directorate-General for Research (MEC) data**

## Research effort of Spanish public universities

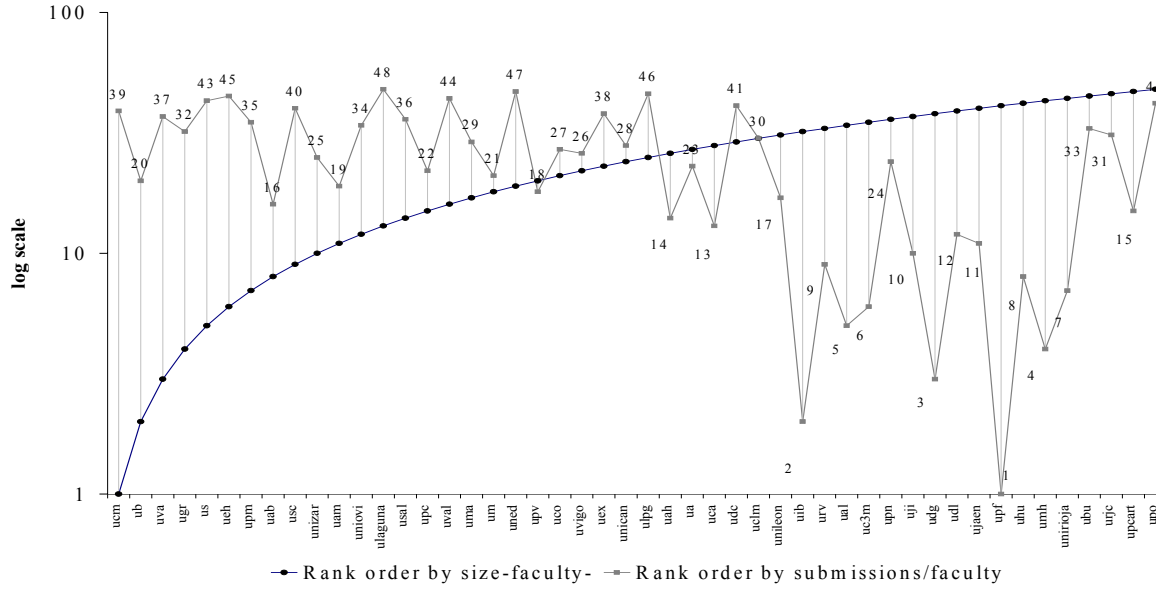
The competitive position of each university with respect to their research capability is influenced by its size. To reduce this bias, in this section, competitiveness is analysed taking into account the size of research organizations. Size seems to be a relevant element in understanding the relative positioning of each research centre or university in the research system; and it is to be expected that the larger universities or centres would also exhibit higher levels of research capabilities both in terms of the number of submissions and of research awards. Here we will analyse the research efforts made by institutions of similar size, and to ensure greater comparability, we will focus, in this section, on public universities because they represent a subset of similar R&D organisations.

The research competitiveness is now measured from the point of their relative efforts. Indexes $RC_3$ and $RC_4$ represent respectively the ratio between the number of R&D project submissions and/or awards and the number of eligible faculty affiliated to each university. The number of faculty members that are eligible as principal investigators are determined by the national calls for applications and they included only tenured faculty members[17]. To conduct our analysis we have lagged the total number of tenured professors two periods, meaning that the size of each university indicates the stock in year 1999. We have proceeded

in this way since new tenures are unlikely to engage in national R&D projects during the first years of their university careers.

Figure 4 shows the distribution according to those values. From the distribution we observe that only a limited number of institutions can be characterized as research-oriented considering the relative effort and involvement in the race for research reputation. Those universities are: Pompeu Fabra –upf-, Carlos III de Madrid –uc3m-, Iles Balears –uib-, Girona –udg- and Miguel Hernández –umh-. All of them share as a common feature that are new universities founded under the auspices of the University Reform Act described in section 2 of this article.

**Figure 4. Rank order in research effort and size. Spanish public universities in the competition for public funding. All research fields 1996-2001.**




**Source: Our own work using Directorate-General for Research (MEC) data**

When relative indicators are introduced, the effects that the different structures introduce in the comparison should not be forgotten, either. When the effect of the size of the universities is eliminated, other characteristic elements of each university can influence their research competitiveness in all dimensions. In addition, distance between $RC_3$ and $RC_4$ shows clear differential levels of competitiveness and represent a first approach to research quality and institutional reputation as well as other factors shaping the final success ratio.

In conclusion, research competitiveness is not only the compound effect of faculty efforts to submit research projects to competitive R&D programs but the returns in terms of R&D grants. Therefore, good performance in this measure of research competitiveness, as a

[17] For our analysis we have included in the Faculty size only the group of tenured faculty that all have PhD that includes: Professors (*Catedráticos de Universidad*), Associated Professors (*Profesores Titulares de Universidad*) and Professors of University Colleges (*Catedráticos de Escuela Universitaria*).

distance between $RC_3$ and $RC_4$ is a distinctive characteristic of only four public universities including Autónoma de Barcelona –ub-, Autónoma de Madrid –uam-, Carlos III de Madrid –uc3m- and Polytechnic of Cataluña –upc-. In contrast, those universities such as Pompeu Fabra –upf-, Miguel Hernandez –umh-, Iles Balears –uib-, and Girona –udg- that were characterized by high levels of effort in applications lost their competitive position dued to relatively higher rates of failure during the peer review process than their competitors in the former group. Moreover the distance could also reflect a much more careful internal selection of proposals process in the former group of universities.

It must be recalled that by aggregating all areas of knowledge, the effects of the structure of disciplines and specialties of each university will also influence their individual ranks. In any case, the indicators constructed to date do not make it possible to observe either very small or very specialised institutions, defects that are also present in traditional bibliometrics. For this reason, we move now to measuring the relative quality of the research at institutions based on their success ratio.

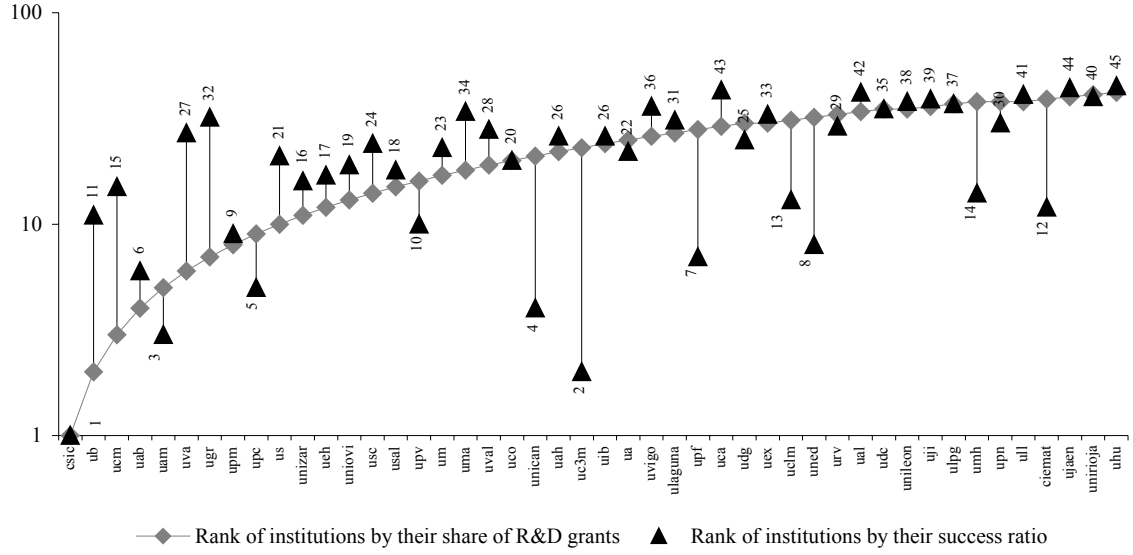
### Research competitiveness and success in the race for national R&D grants

The third dimension of the proposed indicators of research competitiveness refers to the ratio of success of the research institutions. This measurement is perhaps the most accurate one for measuring the relative quality of each public research institution, regardless of its size, as the effects of the peer review subject all institutions to the same restrictions. This ratio gives information regarding the proportion of "good" and "bad" proposals for which each institution is responsible. For the same statistically significant volume of projects presented, a larger success ratio may express higher perceived research quality (determined aggregately in the peer review process the projects undergo)[18].

Figure 5 plots both the rank distribution of the share of R&D awards and the rank distribution of the ratio of success exhibited by each institution ordered by the last one.

[18] One caveat that must be kept in mind is that the success ratio of the projects applying for funding for each R&D programme or research area is diverse; therefore, if a university has greater capabilities in research areas where the success ratio is higher, it will appear with better aggregate results.

**Figure 5. Rank order in ratio of success and absolute research capability. Spanish public research institutions in the competition for public funding. All research fields. 1996-2001.**



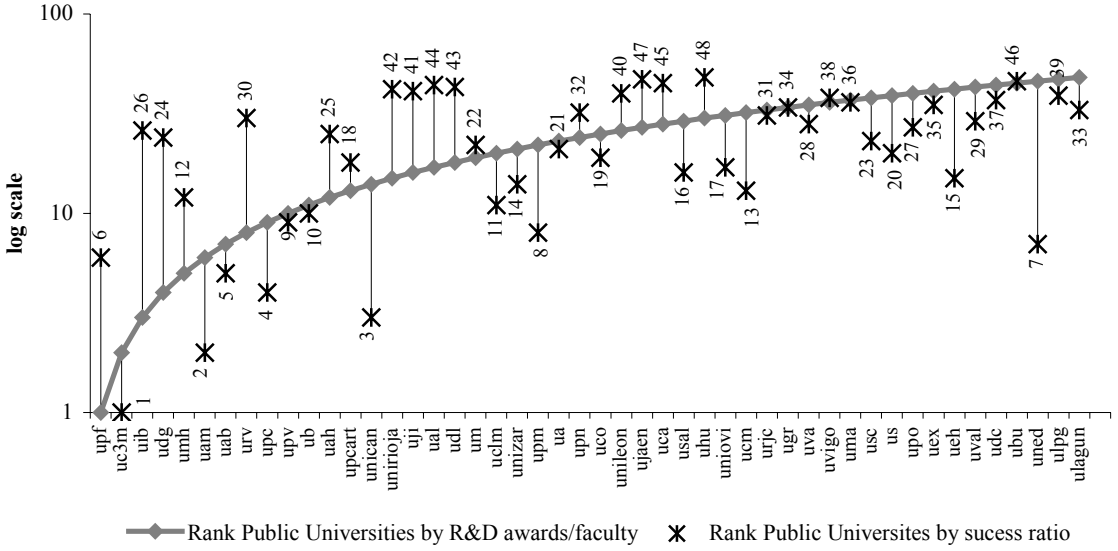

Note.- Only institutions with 10 or more project proposal applications.

**Source: Our own work using Directorate-General for Research (MEC) data**

Universities and R&D centres that are smaller in size, with a high research efforts as well as high success ratios in presenting research projects, are present in the top positions of the rank. In addition, the research success ratio of small centres that carry out research in very specialised areas, such is the case of the Astrophysics Institute of the Canary Islands (IAC), may be greatly influenced by the average success ratio of the programme(s) for which they preferably obtain funding. Thus, it seems that there are two routes for high research competitiveness: large institutions, where the effects of scale are seen, with great internal variety; and relatively small but highly specialised institutions, with a high level of research effort and success.

Figure 6 presents, in terms of the rank positions, the Spanish public universities efforts measures (awards/faculty –$\boldsymbol{RC_4}$–) and their success ratio (ratio of awards on submissions presented –$\boldsymbol{RC_5}$–). It shows how research competitiveness when it refers to the success ratio also appears to be independent of the size of those institutions. Moreover, a higher ratio of awards by faculty may not be related to higher success rates. Those research differences in the relative rank of universities point out the presence of quality differences.

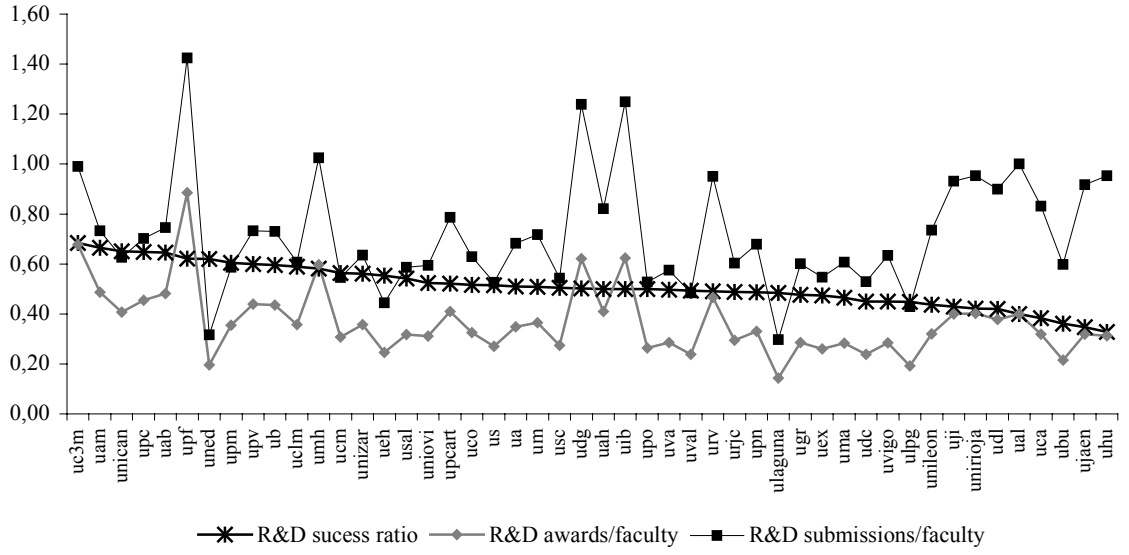
**Figure 6. Rank order in ratio of success and research effort. Spanish public universities in the competition for public funding. All research fields. 1996-2001.**




**Source: Our own work using Directorate-General for Research (MEC) data**

Finally we present the competitive results of the Spanish public universities comparing the results of indicators $RC_5$, $RC_4$, and $RC_3$ (figure 7). Now the picture is much more complex than expected, but it provides relevant information of the different dimensions of research competitiveness of the Spanish Public Universities.

**Figure 7. Research competitiveness. Spanish public universities in the competition for public funding. All research fields. 1996-2001.**




**Source: Our own work using Directorate-General for Research (MEC) data**

## Comparing institutional competitiveness and performance in a research domain: Social and Economic Sciences

We will now present data about competitive research funding in one specific area, Social and Economic Sciences (SES), in order to give an example of the potential of the indicators we are proposing. The approach used makes it possible to analyse in greater detail the data regarding a set of disciplines that generically might be included in the so-called Social and Economic Sciences[19]. This field is interesting to test the suggested hypothesis that competing for national R&D funds reflects reputation and research orientation since funding constraints to conduct research are not as significant as in other disciplines.

There are significant sources of alternative funding for research in these areas; however, between 1996 and 2001, grants totalling 31.3 million euros were awarded, representing 4.14% of the total competitive national government funding for R&D. Funding was requested for a total of 3,113 projects, of which 1,228 were approved –9.37% of the total R&D grants-. A total of 105 institutions and centres applied for funding for R&D projects, but only 65 obtained any funding and 48 out of them are public research centres and universities. Table 2 shows the basic descriptive statistics of the distribution of R&D submissions and awards by the number of competing institutions.

**Table 2. Basic descriptive statistics of Public Research Funds Competition in Social and Economic Sciences. 1996-2001.**

| | Valid N (institutions) | Mean | Confid. -95,000% | Confid. 95,000 | Sum | Minimum | Maximum | Variance | Std.Dev. | Standard Error |
|---|---|---|---|---|---|---|---|---|---|---|
| Submissions | 105 | 31.552 | 21.643 | 41.462 | 3,313 | 1 | 267 | 2,621.826 | 51.204 | 4.9969 |
| Awards | 65 | 18.892 | 12.724 | 25.060 | 1,228 | 1 | 108 | 619,629 | 24.892 | 3.0875 |

| | Valid N (projects) | Mean (euros) | Confid. -95,000% | Confid. 95,000 | Sum (euros) | Minimum (euros) | Maximum (euros) | Variance | Std.Dev. | Standard Error |
|---|---|---|---|---|---|---|---|---|---|---|
| Total funding per grant | 1,228 | 25,477.847 | 24,375.293 | 26,580.401 | 31,286,796.24 | 1,652.78 | 199,247.53 | 387,832,685.30 | 19,693.47 | 561.98 |

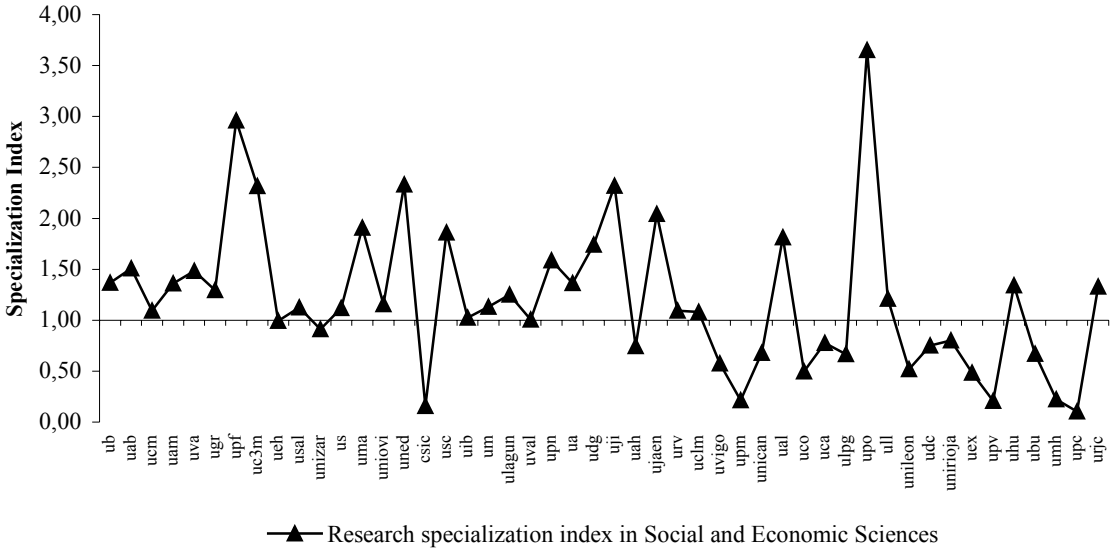
**Source: Our own work using Directorate-General for Research (MEC) data**

The top ten institutions account for about 50% of total grants and R&D funding, and the concentration of Social and Economic Sciences research awards in public research institutions is slightly higher than the observed for all scientific/technical areas. This area is also highly concentrated in public universities (96.7% of total R&D grants), and even some of them are highly dominated by research in Social and Economic Sciences and the National Research Centres play a small role in those areas. To have a clear idea of the degree of specialisation in Social and Economic Sciences of the research institutions we have defined a Research

[19] Competitive calls for proposals awarding funding for research in Social and Economic Sciences have been carried out through a National Socio-Economic Studies Programme (SEC) that funded priority lines of research, and two scientific areas of the General Promotion of Knowledge Programme [Social Sciences (BSO) and Economics (BEC)]; the former includes the

Specialisation Index in Social and Economic Science[20] as a result of the competition for funds, that includes the relative efforts of social and economic sciences with respect to the overall research community (figure 8).

**Figure 8. Research specialization in Social and Economic Sciences. Spanish public research institutions in the competition for public funding. 1996-2001.**




**Source: Our own work using Directorate-General for Research (MEC) data**

From the data it appears that there are some institutions highly specialised in Social and Economic Sciences, the big classical universities and some new universities while other such as the Engineering Universities or the CSIC have less orientation to Social and Economic Sciences. Figure 8 will help to understand the observed differences and the different research capabilities (***RC₁*** and ***RC₂***) in this field, that are higher here than in the aggregate –including all scientific fields-, indicating higher levels of competition among researchers and institutions as well as higher heterogeneity about the quality of research proposals. Moreover, research in Social and Economic Sciences in Spain, and after accounting for the size of faculties, is characterized by substantially low levels of participation and research effort as compared to aggregated figures.

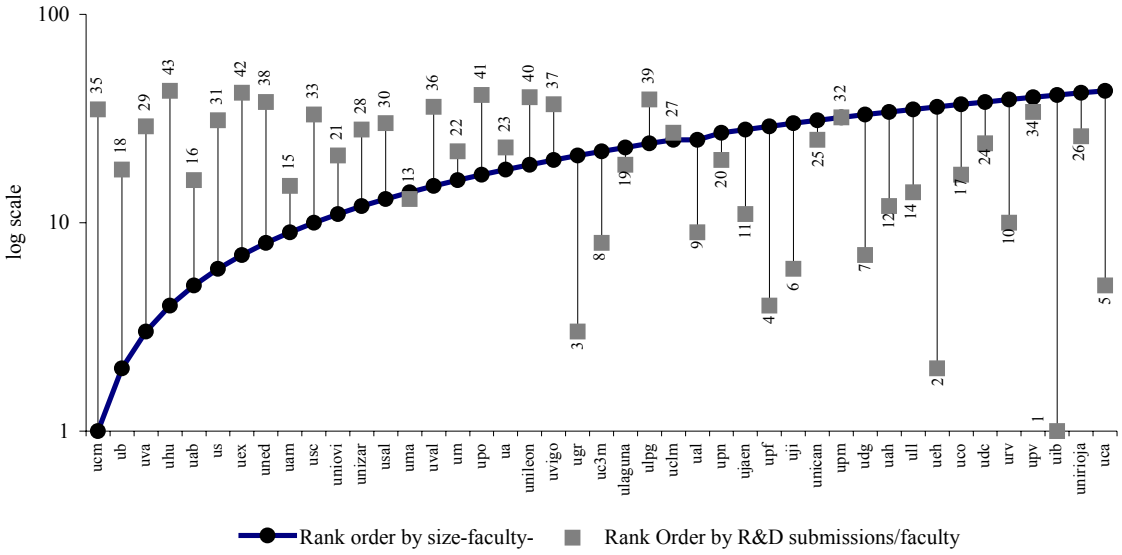
Figure 9 presents the rank order of the universities considering the size of their faculty in Social and Economic Sciences and the ratio of application submissions by faculty, the measure of effort in the search for funding. The results are straight forward in Social and Economic Sciences, faculty in big universities made a substantially smaller effort than faculty

disciplines of Political Sciences and Administration, Sociology, Psychology, Geography, Law and a few other fields, while the latter includes all branches of Economics, including Business Management and Administration.

[20] Research specialization index in Social and Economic Sciences is calculated as follows: [R&D submissions grants in Social and Economic Sciences by institution i/Total R&D submissions in Social and Economic Sciences by public research institutions]/[R&D submissions by institution i in all scientific fields/Total R&D submissions in all scientific fields by public research institutions].

of small universities. For instance, the biggest faculty in Social and Economic Sciences, the Complutense University –ucm- is ranking 35 out of 42 in the effort its researchers are doing in getting funds from competitive programmes.

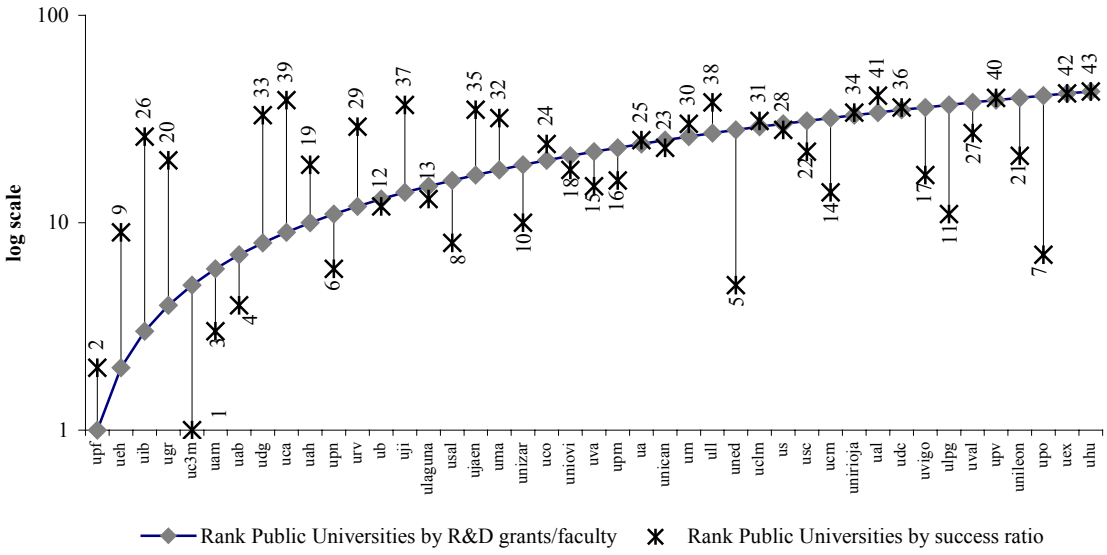
**Figure 9. Rank order in research effort and size. Spanish public universities in the competition for public funding. Social and Economic Sciences. 1996-2001.**




**Source: Our own work using Directorate-General for Research (MEC) data**

The next step in our analysis of the research competitiveness is to compare success ratio (***RC₅***) with the ratio of grants per faculty (***RC₄***) we get a combined picture on research competitiveness associated to quality and success (Figure 10).

**Figure 10. Rank order in ratio of success and research effort. Spanish public universities in the competition for public funding. Social and Economic Sciences. 1996-2001.**




**Source: Our own work using Directorate-General for Research (MEC) data**

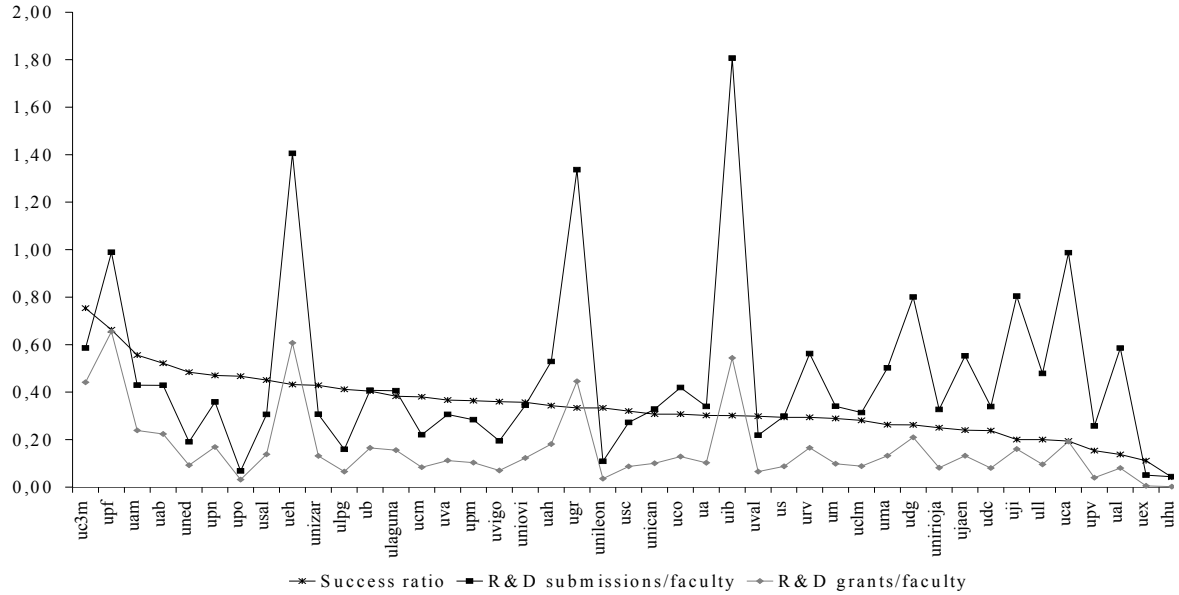
New universities, such as the -uc3m- and –upf- are first in success and effort per faculty, followed by the –uam- and –uab-; however there are other universities, for instance –

uib-, -ueh- or –ugr- that having a strong effort have low levels of success in application in Social and Economic Sciences.

Both measures point out what are the core research institutions in this field at national level. Higher levels of effort by faculty members are an indicator of research commitment and of research values inside the university, but although are not necessary associated to research quality as recognized by peers, but still a factor of differentiation.

Finally we integrate into a single picture three different indicators, the values of $RC_5$, $RC_4$, $RC_3$ (figure 11).

**Figure 11. Research competitiveness. Spanish public universities in the competition for public funding. Social and Economic Sciences. 1996-2001.**



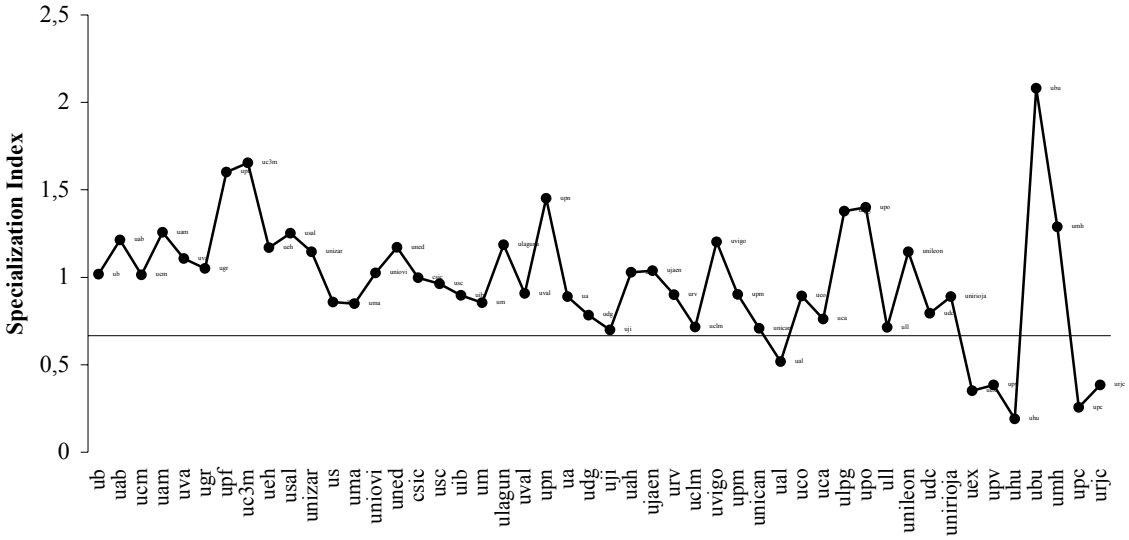

**Source: Our own work using Directorate-General for Research (MEC) data**

Once again, some universities with large research efforts seem to stand out in Social and Economic Sciences, even though they are not the largest universities, because they undoubtedly specialise in these fields. With regard to the data for Social and Economic Sciences, the differentiation between each university's relative rank in the research excellence indicators and its rank in the research capability indicators once again appears. Effort and specialisation appear to be more closely associated with excellence than research capability as an absolute measure.

Finally we present in Figure 12 the differences exhibited by success ratio[21] in the field of Social and Economic Sciences and the aggregate success rate of public research institutions.

[21] The success rate for Social and Economic Sciences proposals was 37.07%, which represents a value that is significantly lower than for R&D projects as a whole, which was 54.26%; then we have normalised the measures according to [Success ratio in SEC by institution$_i$/Average Success ratio in SEC]/[Success ratio in all fields by institution$_i$/Average success ratio in all fields].

**Figure 12 . Differential success ratios (normalised) across institutions in Social and Economic Sciences as compared to success ratios in all scientific areas. Spanish Public Universities. 1996-2001.**




Note.- Only universities with >10 R&D submissions.
**Source: Our own work using Directorate-General for Research (MEC) data**

The picture is also clear, there are universities in which recognitions of the quality of the proposal from their peers in the same field is higher in social and economic sciences than in the all fields together[22]. From such comparisons we conclude that there are a few institutions with a high research reputation on social and economic sciences and that are commonly known by research in this area rather than in other fields. One feature of the Spanish universities is the high variance among the different disciplines, areas of research and departments in terms of reputation, recognition and research competitiveness.

## In conclusion

In this work, we have carried out a pilot exercise in constructing indicators, using information on the results of competition for public research funding with award procedures using peer review, for measuring the research competitiveness of Spanish research institutions, addressing mainly three dimensions of the research activity: capabilities, effort and success.

The procedure for constructing indicators on research competitiveness is theoretically supported by the inclusion of the struggle for funding in the credibility and recognition cycle for the research, and by the growing weight of third-party funding in the operation of research institutions. From a practical point of view, the feasibility of using information on competitive

[22] Some of the extreme values refers to very small universities, with very few proposals, for instance the University of Burgos –ub-.

research funding to produce indicators has been proven, especially those referring to application success which is a result of the ratio of success in approved projects aggregated at the institutional level to projects presented. The unit of observation is the single application for funding of a research proposal, but the level of analysis is the aggregation of these units by research organisations, research centres and universities.

In the case of Spain, there are optimum conditions for the practical feasibility of constructing the indicators, as well as for their theoretical validity. On one hand, the institutions, especially universities, lack their own financial resources to fund research activities, so research organisations need to push their researchers to obtain third-party funding. On the other hand, the source of public funding that has been used to construct the indicators is one that is positively associated with reputation in the context of national research; having a National R&D Plan project approved is a source of recognition as well as one for funding of the research work, so researchers have strong incentives to compete for the approval of research projects in these calls for proposals.

In addition, the technical conditions resulting from the ways research is funded in Spain are also present, making it possible to guarantee the validity of the data. First, the mechanism for approving research project proposals is based on variations of the peer review process. Second, the sources of funding are concentrated in one Ministry that accounts for most of the national government's competitive funds for research projects. Third, the funding of R&D projects is the most important type, and can be differentiated from other funding such as for research equipment, research facilities, individual fellowships, etc. Fourth, all scientific fields go to specific programmes and areas in their search for funding, so an overall view of research activities in Spain can be obtained. Fifth, success ratios are not so small to expect random results in terms of the competition for funds.

There are two additional conditions, which refer to the preferred use of the number of research proposals and not the funding obtained -to avoid the bias of the highly varied cost of research in different scientific areas- and the use of data in multiannual periods -to avoid the bias resulting from the existence of funding application time cycles- that are fulfilled. In the case of Spain, a six years period was used, two call-for-proposal cycles for projects with a duration of three years.

As specific results of the analyses performed using information on competitive research funding in Spain, the existence of a very skewed distribution in research capabilities can be confirmed; a very small number of institutions accounts for most of the research potential in the public sector.

The greatest research capabilities are not always associated with the greatest research efforts of institutions, and they do not necessarily need to correspond to the highest levels of application success. An analysis of the aggregate of research fields and of the breakdown for Social and Economic Sciences shows that application success seems to be more associated with research efforts and, above all, with the level of specialisation of the institutions. Some small research centres and universities that are highly specialised in some areas of research, generally young institutions, lead in research effort and application success as the route for research competitiveness. However, it can also be observed that, in some large institutions with great research capabilities, their economies of scale and wide diversification enable them to offset a lower degree of relevance in some areas with excellence in others.

The construction of indicators using project funding data may be extended to other competitive funding instruments used by governments, as long as the conditions mentioned earlier are present. For later works, another challenge would be to perform an analysis with other levels of aggregation, such as regions, or other multidisciplinary areas of research.

This work, whose aim was to conceptually construct indicators and prove their viability, did not deal with the causes of the diversity of Spanish research institutions in terms of their research capabilities, effort and excellence. Important tasks still remain for another occasion, such as a causal analysis of the variables that may determine research effort and scientific excellence, or a large-scale study of the correlation between the indicators resulting from competitive research funding subjected to peer review and the scientific production and impact indicators that are customarily used in bibliometric techniques, in order to advance towards more complex indicators.

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## Annex 1.- Correspondence of acronyms with the public research centres

| Acronyms[23] | Research Institutions (U. represents University) |
|---|---|
| cedex | CENTRO DE ESTUDIOS Y EXPERIMENTACIÓN DE OBRAS PÚBLICAS |
| ciemat | CENTRO DE INVESTIGACIONES, ENERGÉTICAS. MEDIOAMBIENTALES Y TECNOLÓGICAS |
| csic | CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS |
| iac | INSTITUTO DE ASTROFÍSICA DE CANARIAS |
| ieo | INSTITUTO ESPAÑOL DE OCEANOGRAFÍA |
| inia | INSTITUTO NACIONAL DE INVESTIGACIÓN Y TECNOLOGÍA AGRARIA Y ALIMENTARÍA |
| inta | INSTITUTO NACIONAL DE TÉCNICA AEROESPACIAL |
| itgme | INSTITUTO GEOLÓGICO Y MINERO DE ESPAÑA |
| ua | U. ALICANTE |
| uab | U. AUTÓNOMA DE BARCELONA |
| uah | U. ALCALÁ DE HENARES |
| ual | U. ALMERÍA |
| uam | U. AUTÓNOMA DE MADRID |
| ub | U. BARCELONA |
| ubu | U. BURGOS |
| uc3m | U. CARLOS III DE MADRID |
| uca | U. CÁDIZ |
| uclm | U. CASTILLA-LA MANCHA |
| ucm | U. COMPLUTENSE DE MADRID |
| uco | U. CÓRDOBA |
| udc | U. LA CORUÑA |
| udg | U. GIRONA |
| ueh | U. PAÍS VASCO / EHU |
| uex | U. EXTREMADURA |
| ugr | U. GRANADA |
| uhu | U. HUELVA |
| uib | U. ISLAS BALEARES |
| ujaen | U. JAÉN |
| uji | U. JAUME I |
| ulaguna | U. LA LAGUNA |
| ull | U. LLEIDA |
| ulpg | U. LAS PALMAS DE GRAN CANARIA |
| um | U. MURCIA |
| uma | U. MÁLAGA |
| umh | U. MIGUEL HERNÁNDEZ |
| uned | U. NACIONAL DE EDUCACIÓN A DISTANCIA (UNED) |
| unican | U. CANTABRIA |
| unileon | U. LEÓN |
| uniovi | U. OVIEDO |
| unirioja | U. LA RIOJA |
| unizar | U. ZARAGOZA |
| upc | U. POLITÉCNICA DE CATALUÑA |
| upcart | U. POLITECNICA DE CARTAGENA |
| upf | U. POMPEU I FABRA |
| upm | U. POLITÉCNICA DE MADRID |
| upn | U. PUBLICA DE NAVARRA |
| upo | U. PABLO DE OLAVIDE |
| upv | U. POLITÉCNICA DE VALENCIA |
| urjc | U. REY JUAN CARLOS |
| urv | U. ROVIRA I VIRGILI |
| us | U. SEVILLA |
| usal | U. SALAMANCA |
| usc | U. SANTIAGO DE COMPOSTELA |
| uva | U. VALENCIA |
| uval | U. VALLADOLID |
| uvigo | U. VIGO |

[23] Acronyms used correspond, in most cases, to the name of the internet domains.